



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



**International University of Africa**  
**Faculty of Pure and Applied Sciences**

**Study the Effect of X-Ray on**  
**Bipolar Junction Transistor (BJT) NPN 129**

**By: Asia Ibrahim Arbab Abdalla**

**A dissertation Submitted in Partial Fulfillment of the Requirements for**

**M.Sc. Degree in Medical Physics**

**Supervisor: Dr. Omer Mohammed Adam Adllan**

***March 2017***

## الآية

قال تعالى:

« اللهُ نُورُ السَّمَاوَاتِ وَالْأَرْضِ مِثْلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ الْمِصْبَاحُ فِي زُجَاجَةٍ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِنْ شَجَرَةٍ مُبَارَكَةٍ زَيْتُونَةٍ لَا شَرْقِيَّةٍ وَلَا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ لَمْ تَمْسَسْهُ نَارٌ نُورٌ عَلَى نُورٍ يَهْدِي اللهُ لِنُورِهِ مَنْ يَشَاءُ وَيَضْرِبُ اللهُ الْأَمْثَالَ لِلنَّاسِ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ» (35)

صدق الله العظيم

سورة النور - الآية (35)

## **Dedication**

To my lovely parents,

To my family's love patience, support and care were essential  
all the time to accomplish this project.

To my friends and my colleagues.

To my medical physics family.

I dedicate this work to you.

## **Acknowledgement**

In the Name of Allah, the most Beneficent, the most Merciful. First Praise is to Allah, and peace and blessings upon the noblest Messengers, and his Prophet Mohammed and on his family and all his companions.

I would like to express my sincere gratitude to my supervisor Dr. Omer Mohammed Adam Adllan, for his support, invaluable guidance , time, and for teaching me how to express myself in a more comprehensive way. His critical reading of the text and suggestions are greatly acknowledged.

I would especially like to thank the great Medical physicists in the medical physics group and also my thanks goes to a number of my colleagues .

Finally I would like to thanks my family, mainly my mother, for their love, support and being patient to keep all my dreams to be real.

## Abstract

This project is aimed to study the effect of radiation (X-ray) on BJT transistor parameters characteristic (**129-NPN**) was exposed and used in technology as a radiation detector. When transistor (**129-NPN**) was exposed by (X-ray) for different time sequences and supply of certain voltage (35) kv and current (1) mA. It found that the value of collector current ( $I_c$ ) and collector voltage ( $V_C$ ), base Emitter voltage ( $V_{BE}$ ) and collector Emitter voltage ( $V_{CE}$ ) with the fixed of the value of base current ( $I_B$ ). After exposing the following values are calculated ( $\beta_{DC}$ ), Electrical conductivity ( $Z$ ) and Electrical resistance ( $gm$ ). And indicate of a reduction in the value of the complex Emitter current ( $I_E$ ), collector current ( $I_C$ ) and ( $\beta_{DC}$ ) with different time of irradiation.

The importance of the project came from that (X-ray) radiation is hazardous therefore detected it, so the transistor in this project has been used to detect any irradiation doses and it can be used as a radiation detector.

Also in this project was recommended that to use different amount of radiation doses in appropriate conditions.

## المستخلص

إن هذا البحث يهدف إلى دراسة تأثير الأشعة السينية على خصائص الترانزستور. (NPN(129) وما يحدث له من تغير من أجل استخدامها في التكنولوجيا ككاشف للأشعة السينية. تم تسليط الأشعة السينية (X-RAY) بفرق جهد مقداره ( 35V ) وبتيار (1mA) على الترانزستور الموصل في دائرة كهربية كمضخم للتيار لفترات زمنية متتالية ( 5,10,15,20,25,30,35,40,45,50 ) عند ثبوت قيمة تيار القاعدة  $I_B$  تم قياس جهد القاعدة (B) ، جهد الباعث المجمع ( $V_{CE}$ ) وتيار المجمع . وأيضاً تم حساب قيمة العامل ( $\beta_{DC}$ ) وقيمة الموصلية الكهربائية (gm) والممانعة الكهربائية. (Z) لوحظ انخفاض إن هناك انخفاض في القيم المذكورة اعلاه مع أزمان مختلفة من التشعيع . تأتي أهمية هذا الدراسة إن الأشعة السينية أشعة ضارة مالم يتم الكشف عنها لذلك تم استخدام الترانزستور في دائرة كمضخم للتيار ليتم بواسطته استشعار الإشعاع . كذلك تم التوجيه في هذه الدراسة أن تؤخذ القراءات عن تطبيق جرعات مختلفة من الأشعة السينية وذلك عند توفر الظروف الملائمة.

## Contents

No	Items	Page no
1	الأيّة	I
2	Dedication	II
3	Acknowledgments	III
4	Abstract	IV
5	المستخلص	V
6	Contents	VI
7	List of Tables	VIII
8	List of Figure	IX
9	Abbreviation	X
<b>Chapter one : Introduction</b>		
10	1.1 Introduction	1
11	1.2.Problem Statement	1
12	1.3objectives	1
13	1.3.1 General objectives	1
14	1.3.2 Specific objectives	1
15	1.4 Thesis outline	2
16	1.5 Literature review	3
<b>Chapter Two : background theory</b>		
17	2.1 Classification of materials as energy ranges	5
18	2.1.1 A conductor	5
19	2.1.2 Insulator	5
20	2.1.3 Semiconductors	5
21	2.2 Energy Bonds	6
22	2.3 Comparison of a semiconductor to conductor atom	7
23	2.4 Covalent Bonds	8
24	2.5 Conduction in semiconductors	10
25	2.6 Conduction Electron and Holes	11
26	2.7 Electron and Hole current	13
27	2.8 Doping	14
28	2.8.1 N- Type semiconductors	14

29	2.8.2 P– type semiconductor	15
30	2.9 A diode	16
31	2.9.1 Forward Bias	17
32	2.9.2 Reverse Bias	19
33	2.9.3 Reverse break down	20
34	2.10 Introduction to Transistors	20
35	2.11 Types of Transistor	21
36	2.11.1 Bipolar Junction Transistors	21
37	2.11.1.1 NPN Transistor	22
38	2.11.1.2 PNP Transistor	23
39	2.12 Transistor currents	24
40	2.13 Transistor Characteristics and Parameters	25
41	2.14 Transistor temperature stability	27
42	2.11.2 Field Effect Transistors	28
43	2-15 Schottky defect	28
44	2.16 X-ray	31
45	2.17 Properties	32
46	2.18 Interaction with matter	32
47	2-18.1 Photoelectric absorption	33
48	2.18.2 Compton scattering	33
49	2.18.3 Coherent (Rayleigh) scattering	34
50	2.19 Mechanism	35
51	2.20 X-ray beams and X-ray units	36
52	2.20.1 characteristic X-ray	36
53	2.20.2 bremsstrahlung X rays	37
54	2-21 X-Ray Safety	37
55	2.21.1 General	37

56	2-21-2Causes of Accidental Exposures	37
57	2.21.3Four Main Causes of Accidents	38
58	2.21.4Four Main Causes of Accidents	38
	<b>Chapter Three : Material and Methods</b>	
59	3. Material and Methods	39
60	3.1 Electronic circuit	39
61	3-2 Tools irradiation experiment	39
	<b>Chapter Four : Results and Discussion</b>	
62	4 Results and Discussion	41
63	4.1 Result	41
64	4.2 Discussion	45
	<b>Chapter Five : Conclusion and recommendations</b>	
65	5 Conclusion and recommendations	46
66	5.1 Conclusion	46
67	5.2 Recommendations	76
68	5.3. References	48

## **LIST OF Tables**

<b>No</b>	<b>Table</b>	<b>P no</b>
1	Table (2-1) Comparison between the Silicon (si) and Germanium(ge) in manufacturing of the important parameters	29
2	Table (2-2) A table showing the most important constants of semiconductor.	29
3	Table (2-3) Shortlist constants illustrates the most important semiconductor.	30
4	Table (3-1) X-ray parameter.	39
5	Table (4-1) changes in fundamental characteristics of the transistor.	42

## LIST OF FIGURES

No	FIGURES	P no
1	Figure(2-1): shown energy diagrams for (a)insulator, (b)semiconductors, and(c) conductors.	7
2	Figure (2-2) :diagram of the silicon and copper atom.	8
3	Figure (2- 3): illustration of covalent bonds in silicon	10
4	Figure (2- 4): covalent bonds in a silicon crystal	10
5	Figure (2- 5): Energy band diagram for an unexcited atom in a pure (intrinsic) silicon crystal. There are no electrons in the conduction band.	11
6	Figure (2-6): creation of electron hole pairs in silicon crystal electronic the conduction band are free electrons.	12
7	Figure (2-7): electron hole pairs in a silicon crystal.	12
8	Figure (2-8): electron current in intrinsic silicon is produced by The move.	13
9	Figure (2-9): hole current in intrinsic silicon mint of thermally generated free electrons.	14
10	Figure (2-10):Pentavalent impurity atom in a silicon crystal structure. An antimony (Sb) impurity atom is shown in the center.	15
11	Figure (2-11): Trivalent impurity atom in silicon crystal structure. A boron (B) impurity atom is shown in the center.	16

12	Figure (2–12) :In(a)(b)The PN-Junction.	17
13	Figure (2– 13):A diode Connected Forward Bias.	18
14	Figure(2– 14) : A forward -biased diode showing the flow of majority carriers and the voltage due to the barrier potential across the depletion region.	18
15	Figure(2–15): (a) The diode during the short transition time immediately after reverse bias voltage is applied . In (b) the extremely reverse current in reverse-biased is due to the minority carriers from thermally generated electron-hole pairs.	19
16	Figure(2-16):curve for reverse break down.	20
17	Figure (2-17) :Types of Transistors.	21
18	Figure (2-18 ): Bipolar junction transistors PNP & NPN.	21
19	Figure ( 2-19):NPN Transistor configuration .	23
20	Figure ( 2-20):PNP Transistor configuration .	24
21	Figure (2-21) :Transistor currents.	25
22	Figure (2-22) : $V_{BB}$ forward biases the bas emitter junction when the based emitter junction is forward.	26
23	Figure (2– 23) Dc load line on a family of collector characteristic curves illustrating the cut off and saturation conditions.	27
24	Figure( 2-24): The Electromagnetic Spectrum.	31

25	Figure (2-25): Drawing of a typical X-ray tube.	36
26	Figure(3-1): X-Ray machine	40
27	Figure (3-2): BJT Transistor NPN(129) Electric Circuit.	40
28	Figure(4-1): ): Relationship between $I_C$ and $Z$ .	42
29	Figure(4-2) : Relationship between $I_C$ and $V_{CE}/V$ .	43
30	Figure(4-3): Relationship between $Z$ and time/min.	43
31	Figure (4-4): Relationship between $g_m$ and time/mine.	44
32	Figure (4-5) : Relationship between $\beta_{(DC)}$ and time/min.	44
33	Figure (4-6): Relationship between $V_B$ and time/min.	44

## List of Abbreviations

No	Abbreviations
1	<b>SI</b> silicon
2	<b>Ga</b> germanium
3	<b>n</b> electron
4	<b>p</b> hole
5	<b>P</b> phosphorus
6	<b>As</b> arsenic
7	<b>Sb</b> antimony
8	<b>In</b> indium
9	<b>Ga</b> gallium
10	<b>B</b> Boron
11	<b>dc</b> direct current
12	<b>BJT</b> Bipolar Junction Transistors.
13	<b>NPN</b> negative-positive-negative transistors.
14	<b>PNP</b> Positive-Negative-Positive transistors.
15	<b>I<sub>E</sub></b> Emitter current.
16	<b>I<sub>C</sub></b> collector current.
17	<b>I<sub>B</sub></b> base current.
18	<b>V<sub>BE</sub></b> dc voltage at base with respect to emitter.
19	<b>V<sub>CB</sub></b> dc voltage at collector with respect to base.
20	<b>V<sub>CE</sub></b> dc voltage at base with collector with respect to emitter.
21	<b>V<sub>BB</sub></b> forward biases the bas emitter junction when the based emitter junction is forward.
22	<b>β<sub>DC</sub></b> DC Beta.
23	<b>α<sub>DC</sub></b> DC Alpha.
24	<b>R<sub>B</sub></b> base – resistance.
25	<b>R<sub>E</sub></b> emitter– resistance.
26	<b>I<sub>C</sub></b> collector – current.

27	<b>V<sub>BE</sub></b> (base – emitter) voltage.
28	<b>T</b> temperature induced minority .
29	<b>I<sub>CBO</sub></b> carrier current.
30	<b>NA</b> Avogadro’s number. <b>C</b> speed of light in vacuum.
31	<b>V<sub>BE</sub></b> (base – emitter) voltage.
32	<b>m<sub>p</sub></b> Proton rest mass.
33	<b>m<sub>n</sub></b> Neutron rest mass.
34	<b>u</b> Atomic mass unit.
35	<b>KV</b> kilo voltage.
36	<b>mA</b> mill amperage.
37	<b>m<sub>p</sub></b> Proton rest mass.
38	<b>Z</b> atomic number.
39	<b>E</b> the energy.
40	<b>E<sub>K</sub></b> a kinetic energy.
41	<b>S</b> is known as the incoherent scattering function.